

A COMPREHENSIVE STUDY OF DIFFERENT ENERGY-EFFICIENT ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

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ABSTRACT

The network of Sensor Nodes communicating in a wireless manner is referred to as Wireless Sensor Network. With the advent of time deployment of WSNs for real life application is greater than before. but still, the energy constraint remains one of the key issues and prevents the complete utilization of WSN technology. One of the solution is to have Clustering routing protocols as they reduces the transmission distance which results in less energy consumption and thereby increasing the life of the WSN. This paper presents review on some of the different Clustering routing protocols being used in WSN. Along with that some of the applications of WSNs are also listed.

KEYWORDS:-Sensor-Nodes, Base-Station, Cluster-Head

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INTRODUCTION

A Wireless Sensor Network also known as Wireless Sensor and Actuator Network is the network of sensor nodes from few to several hundreds or even thousands distributed over an area to monitor physical or environmental conditions. Size and Cost of the sensor nodes varies. Figure 1 shows a Sensor Network Arrangement which comprises of following elements:

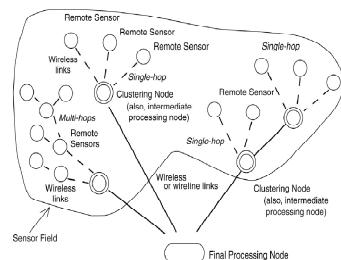


Figure.1: Sensor Network Arrangement

- **Remote Sensors:** Are those sensor nodes who senses the environmental conditions and forward the data to the intermediate processing node which further passes on the sensed data to the final processing node.
- **Clustering Node:** Also known as Cluster Head is the one which performs data fusion, data aggregation and then forwards the refined data to the final node so as to reduce the energy consumption by preventing the unnecessary transfer of the data to the final processing node.
- **Final Processing Node:** Also known as Base-Station. On receiving the data from the Cluster Head analyses the data and then data is retrieved as per requirement.

Remote Sensor Nodes after sensing the data forwards the sensed data to the Clustering Node or Cluster Head either through single-hop or multi-hops mode of communication. Single-hop means that remote sensor nodes directly forward the sensed data to the CH as they are directly connected to Clustering Node whereas Multi-hop means that remote sensor nodes first forward the data to the other remote sensor nodes which then forward the data to the CH. CHs on receiving the data from remote sensor nodes forward the sensed data to the Final Processing Node or Base-Station.

Each sensor node in a network consist of following parts:

- A Radio Transceiver with an internal antenna.
- A microcontroller.
- An electronic circuit for interfacing with the sensors and an energy source.

This paper is divided into five sections:-first section gives Introduction, second and third section describes Characteristics of Wireless Sensor Network and Various Routing Protocols used in Wireless Sensor Networks respectively, fourth section gives review of different energy efficient routing protocols being proposed, fifth section presents applications of wireless sensor network and atlast sixth and seventh section presents Conclusion and References respectively.

Characteristics of wireless sensor networks

Some of the characteristics of WSNs are listed as follows:

- Sensor nodes are densely deployed.
- Sensor nodes are prone to failures.
- Sensor nodes are limited in power, computational capacities, and memory.
- Sensor nodes may not have global identification because of the large amount of overhead and the large number of sensors.

Routing Protocols

Routing Protocols in WSNs can be divided on the basis of Path Establishment, Network Structure, Protocol Operation and Initiator of Communication. On the basis of Network Structure we can further divide the Routing Protocols into three categories Location-Based, Hierarchical and Flat. This paper focuses on Hierarchical Routing Protocols. These protocols work in two layers first layer is used to choose cluster head and second layer is used for routing. In order to make WSN more energy efficient clusters are created and on each cluster a cluster head is selected and assigned special task of data aggregation and fusion. Hierarchical Routing Protocols are one of the most energy efficient routing protocols for WSNs, as they reduce the transmission distance between Sensor nodes and the Base-Station by formation of clusters and Cluster Head which results in reduction of energy consumption and thereby increases the Lifetime of the network. Some of the Clustering Routing Protocols are mentioned as follows:-LEACH, PEGASIS, HEED,EEUC ,EAST, Q-LEACH, ACH, DWEHC, PANEL, TL-LEACH, UCS, EECS, ACE, BCDCP, TEEN, APTEEN, TTDD, CCS, HGMR, Hybrid Energy Efficient Reactive Protocol and many more. Some of them are discussed in this paper.

Literature Review

Wendi et al. [2000] proposed “Energy-Efficient Communication Protocol for Wireless Microsensor Networks”[1].In this paper author proposed a clustering-based protocol LEACH that ensures randomized rotation of cluster head so as to distribute energy evenly among all sensor nodes and alast performed comparison of LEACH with other existing conventional routing protocols and showed that LEACH outperforms them in terms of reduction of energy dissipation.

Lindsey et al. [2002] proposed “PEGASIS: Power-efficient gathering in sensor information systems”[2].In this paper author proposed PEGASIS routing protocol in which chain is formed by connecting each sensor node to the next sensor node for transferring data from source to sink. Implementing this topology is very difficult as chain formation process requires global knowledge of sensor nodes.

Younis et al. [2004] proposed “HEED: a hybrid energy-efficient,distributed clustering approach for adhoc sensor networks”[3].In this paper author proposed a clustering based protocol HEED in which cluster head is selected on the basis of probability which is related to residual energy of the sensor nodes.One of the drawback with this clustering protocol is that the sensor nodes with minimum residual energy can acquire higher probability to become cluster head.

N.Javaid et al. proposed [2013] “HEER: Hybrid Energy Efficient Reactive Protocol for Wireless Sensor Networks”[4].In this paper author proposed a hybrid protocol in which cluster head election is based on energy,one is the residual energy of the sensor nodes and other is the average energy of the network.

Tahir et al. [2013] proposed “On Adaptive Energy-Efficient Transmission in WSNs”[5].In this paper author proposed an EAST routing protocol that make use of two feedback processes one i.e. open-looping feedback process and the other closed-loop feedback process for temperature-aware link quality estimation and to minimize overhead of control packets by dividing the network into regions respectively.

B.Manzoor et al. [2013] proposed “Q-LEACH: A New Routing Protocol for WSN”[6].In this paper author proposed Quadrature-LEACH designed for homogeneous Wireless Sensor Network and showed that proposed routing protocol maximizes the stability period,throughput and lifetime of network.

Smaragdakis et al. [2004] proposed “SEP: A stable election protocol for clustered heterogeneous wireless sensor networks”[7].In this paper author proposed a protocol for heterogeneous sensor network which comprises of nodes with different initial energy. Cluster Head selection in this protocol depends on the initial energy of the sensor nodes also showed that this protocol did not perform good in case of multi-level Heterogeneous networks.

Loscri et al. [2005] proposed “A two-levels hierarchy for low-energy adaptive clustering hierarchy(TL-LEACH)”[8].In this paper author proposed clustering protocol that make use of two level clustering scheme. Level one cluster head directly communicate with the sensor nodes and level two cluster head creates clusters from cluster head of level one. Implementation of this scheme showed that it resulted in reduction of energy consumption of the network.

Li et al. [2005] proposed “An energy-efficient unequal clustering mechanism for wireless sensor networks”[9].In this paper author proposed an unequal clustering protocol which attempts to balance the energy consumption of the network by dividing the network field into unequal clusters.One of the drawback with this protocol is that there can exist some nodes not associated with any cluster.

N.Javaid et al. [2013] proposed “ACH:Away Cluster Heads Scheme for Energy Efficient Clustering Protocols in WSNs”[10].In this paper author proposed Away Cluster Head Protocol for Wireless Sensor networks. Implementation of this protocol resulted in maximization of throughput and stability period of the sensor network.

Heinzelman et al. [1999] proposed “Adaptive protocol for information dissemination in wireless sensor networks”[11].In this paper author proposed Sensor Protocol for Information Via Negotiation in which sensor nodes after sensing the data broadcasts the type of sensed data to all its neighbours after this all the interested neighbours will then send request to the originating sensor node for copy of data.In this manner, all the nodes obtain the data.But one of the drawback with this approach is that it does not ensures data delivery to each sensor node in the network.

Fan et al. [2007] proposed “Improvement on LEACH Protocol for Wireless Sensor Networks”[12].In this paper author proposed energy-LEACH and multi-hop LEACH protocols.Energy-LEACH protocol and Multi-Hop LEACH improved the existing LEACH protocol by introducing the concept of residual energy for Cluster Head selection and by switching the communication mode between Cluster Head and Sink from single-hop to multi-hop.And atlast performed the comparison of LEACH with the Energy-LEACH and Multi-Hop LEACH and showed that they outperforms LEACH.

Ding et al. [2005] proposed “A. Distributed Energy Efficient Hierarchical Clustering for Wireless Sensor Networks”[13]. The main objective of this research was to improve HEED by building balanced cluster sizes and optimize the intra-cluster topology using location awareness of the nodes.

Q.Nadeem et al. [2013] proposed “M-GEAR: Gateway Based Energy-Aware Multi-Hop Routing Protocol for WSNs”[14].In this paper author proposed gateway based energy efficient routing protocol. And at last compared with the existing LEACH and showed that it outperforms LEACH.

Soro et al. [2005] proposed “Prolonging the Lifetime of Wireless Sensor Networks via Unequal Clustering”[15].In this paper author proposed Unequal Clustering Size Model for balancing energy consumption of Cluster Heads and thereby further improving the Lifetime of Wireless Sensor Networks.

Murugunathan et al. [2005] proposed “A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks”[16].In this paper author proposed Base-Station Controlled Dynamic Clustering Protocol in which base station is capable of performing complex computations.

Manjeshwar et al. [2001] proposed “TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks”[17].In this paper author proposed Threshold sensitive Energy Efficient sensor Network protocol which combines the hierarchical technique with the data centric approach.Energy Consumption in this protocol is less as data transmission is done less frequently.

Manjeshwar et al. [2002] proposed “APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks”[18].In this paper author proposed Adaptive Threshold sensitive Energy Efficient sensor Network protocol which is an extension of TEEN and changes the threshold values used in TEEN according to the requirement of users and the type of application and because of which can be used in both reactive and proactive applications.

Luo et al. [2005] proposed “TTDD: Two-tier data dissemination in large-scalewireless sensor networks”[19].In this paper author proposed Two-Tier Data Dissemination protocol which is a low-power protocol for efficient data delivery

from multiple sources to multiple mobile sinks.

Jung et al. [2007] proposed “The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS”[20].In this paper author proposed Concentric Clustering Scheme to reduce the energy consumption loopholes in PEGASIS. The main idea of CCS is to consider the location of the BS to enhance its performance and to prolong the lifetime of the network.

Applications

WSNs are collection of nodes that measure environmental conditions or other parameters and forward the data to the central station for Processing. There are wide range of applications of WSNs some of them are listed below:

Military Applications:

- **Battle damage assessment.**
 - Nuclear, biological, and chemical attack detection.
 - Monitoring friendly forces and equipment.
 - Monitoring inimical forces and more.
- **Environmental Applications:**
 - Forest fire detection.
 - Flood detection.
 - Precision agriculture and more.
- **Health Applications:**
 - Drug administration.
 - Elderly assistance.
 - Tracking and monitoring doctors and patients inside a hospital and more.
- **Home Applications:**
 - Home automation.
 - Instrumented environment and more.
- **Commercial Applications:**
 - Environmental control in industrial and office buildings.
 - Inventory control.
 - Vehicle tracking and detection and more.

CONCLUSIONS

A Key concern in Wireless Sensor Network is to reduce the energy consumption and thereby improving the

lifetime of the sensor network. Since the year 2000 there have been much research in the field of Wireless Sensor Network. From the year 2000 to 2010 LEACH, PEGASIS, HEED, SEP, TL-LEACH, EEUC, TEEN, APTEEN and TTDD were some of the energy-efficient routing protocols being proposed for wireless sensor network and from the year 2011 till date HEER, EAST, Q-LEACH, ACH and M-GEAR are some other proposed routing protocols.

REFERENCES

1. Heinzelman, Wendi Rabiner, Anantha Chandrakasan, and Hari Balakrishnan. "Energy-efficient communication protocol for wireless microsensor networks." *System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference on*. IEEE, 2000.
2. Lindsey, Stephanie, and Cauligi S. Raghavendra. "PEGASIS: Power efficient gathering in sensor information systems." *Aerospace conference proceedings, 2002. IEEE*. Vol. 3. IEEE, 2002.
3. Younis, Ossama, and Sonia Fahmy. "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks." *Mobile Computing, IEEE Transactions on* 3.4 (2004): 366-379.
4. N. Javaid, S. N. Mohammad, K. Latif, U. Qasim and Z. A. Khan, M. A. Khan, "HEER: Hybrid Energy Efficient Reactive Protocol for Wireless Sensor Networks", 2nd IEEE Saudi International Electronics, Communications and Photonics Conference (SIECPC 13), 2013, Riyadh, Saudi Arabia.
5. Tahir, M., et al. "On Adaptive Energy-Efficient Transmission in WSNs." *International Journal of Distributed Sensor Networks* 2013 (2013).
6. B. Manzoor, N. Javaid, O. Rehman, M. Akbar, Q. Nadeem, A. Iqbal, M. Ishfaq, "Q-LEACH: A New Routing Protocol for WSN", *International Workshop on Body Area Sensor Networks (BASNet-2013) in conjunction with 4th International Conference on Ambient Systems, Networks and Technologies (ANT 2013)*, 2013, Halifax, Nova Scotia, Canada, *Procedia Computer Science*, Volume 19, 2013, Pages 926-931, ISSN 1877-0509.
7. Smaragdakis, Georgios, Ibrahim Matta, and Azer Bestavros. "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks". *Boston University Computer Science Department*, 2004.
8. Loscri, V., G. Morabito, and S. Marano. "A two-levels hierarchy for low-energy adaptive clustering hierarchy (TL-LEACH)." *IEEE Vehicular Technology Conference*. Vol. 62. No. 3. IEEE, 1999, 2005.
9. Li, Chengfa, et al. "An energy-efficient unequal clustering mechanism for wireless sensor networks." *Mobile Adhoc and Sensor Systems Conference, 2005. IEEE International Conference on*. IEEE, 2005.
10. N. Javaid, M. Waseem, Z. A. Khan, U. Qasim, K. Latif and A. Javaid, "ACH: Away Cluster Heads Scheme for Energy Efficient Clustering Protocols in WSNs", 2nd IEEE Saudi International Electronics, Communications and Photonics Conference (SIECPC 13), 2013, Riyadh, Saudi Arabia
11. Heinzelman, Wendi Rabiner, Joanna Kulik, and Hari Balakrishnan. "Adaptive protocols for information dissemination in wireless sensor networks." *Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking*. ACM, 1999.
12. Liangrui Tang and Sheng Liu, "Improvement on LEACH Routing Algorithm for Wireless Sensor Networks" in *Internet Computing & Information Services (ICICIS)*, 2011 International Conference.
13. Ding, Holliday and Celik "Distributed energy-efficient hierarchical clustering for wireless sensor networks" in *DCOSS'05 Proceedings of the First IEEE International conference on Distributed Computing in Sensor Systems*

14. Q.Nadeem,M.BRasheed,N.Javaid,Z.A.Khan,Y.Maqsood and A.Din "M-GEAR: Gateway-Based Energy-Aware Multi-Hop Routing Protocol for WSNs".*IEEE 8th International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA'13)*, Compiegne, France.
15. Soro, S.; Heinzelman, W. *Prolonging the Lifetime of Wireless Sensor Networks via Unequal Clustering*. In *Proceedings of the 5th IEEE International Workshop on Algorithms for Wireless, Mobile, Ad Hoc and Sensor Networks (WMAN)*, Denver, CO, USA, 4–8 April 2005; pp. 236–243.
16. Murugunathan, S.D.; Ma, D.C.F.; Bhasin, R.I.; Fapajuwo, A.O. *A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks*.*IEEE Radio Commun.* 2005, 43, S8–S13..
17. Manjeshwar, E.; Agrawal, D.P. *TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks*. In *Proceedings of the 15th International Parallel and Distributed Processing Symposium (IPDPS)*, San Francisco, CA, USA, 23–27 April 2001; pp. 2009–2015.
18. Manjeshwar, A.; Agrawal, D. P. *APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks*. In *Proceedings of the 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile computing*, Lauderdale, FL, USA, 15–19 April 2002; pp. 195–202.
19. Luo, H.; Ye, F.; Cheng, J.; Lu, S.; Zhang, L. *TTDD: Two-tier data dissemination in large-scale wireless sensor networks*.*Wirel. Netw.* 2005, doi:10.1007/s11276-004-4753-x.
20. Jung, S.; Han, Y.; Chung, T. *The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS*. In *Proceedings of the 9th International Conference on Advanced Communication Technology*, Gangwon-Do, Korea, 12–14 February 2007; pp. 260–265.
21. Yogesh Kumar Dhingra and Hardwari Lal Mandoria "End to End Delay and Packet Delivery Ratio Analysis of Leach Protocol In Wireless Sensor Network". *INTERNATIONAL JOURNAL FOR RESEARCH IN EMERGING SCIENCE AND TECHNOLOGY, VOLUME-2, ISSUE-8, AUG-2015*
22. Rajat Kandpal, Rajesh Singh and H L Mandoria "Analysis on Enhancements in LEACH Protocol for WSN".*International Journal of Computer Science and Engineering (SSRG-IJCSE)* by SSRG – IJCSE Journal Volume-2 Issue-9.
23. Pranavi Tayal, Hardwari Lal Mandoria, Renu Bahuguna "A Study of energy efficient data collection approaches in Wireless Sensor Network" in *Proceedings of national conference on trends in signal processing & communication (TSPC'13)*.
24. Pranavi Tayal, Hardwari Lal Mandoria, Himanshu Chanyal "Simulation in Wireless Sensor Network: A Review" in *Proceedings of National Conference on Trends in Signal Processing & Communication (TSPC'13)*.
25. Mohit Mungali, Rajesh Singh & Hardwari Lal Mandoria "Performance Analysis of LEACH Protocol for Wireless Sensor Network" in *i-manager's Journal on Wireless Communication Networks*
26. Pranavi Tayal, Hardwari Lal Mandoria, Himanshu Chanyal "Energy Efficient agent based approach for data aggregation in wireless sensor network" in *International Journal of Wired and Wireless Communications*.
27. Kashniyal J, H.L. Mandoria "Energy Efficient Analysis between AODV LEACH and LEACH- E using Castalia" in *International Journal of P2P Network Trends & Technology*.
28. Rohit Rawat, H.L. Mandoria "Evaluation of Traffic Monitoring Wireless Sensor Network System under the Effect of Various Climatic Conditions" in *International Journal of Computer Science & Engineering Technology*.
29. Rajat Kandpal, Rajesh Singh, Hardwari Lal Mandoria "Comparative Study of Hierarchical Routing Protocols in Wireless Sensor Networks" in *International Journal of Computer Science Engineering*.

30. *Manoj Kumar Joshi and Hardwari Lal Mandoria* “A review on wireless adhoc network security” in *International Journal of Engineering Sciences and Research Technology*.